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The seed coats of Malvaceæ.*

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(WITH PLATE III.)

Much attention has been given to the rich field of development and structure of seed coats. Most of the work has been done by European investigators. American botanists are rapidly taking up the work, and are studying not only the seed coats but the entire anatomical plant structure.

Of the investigators who have given the matter of seed coats attention, Gaertner,[1] Bischoff,[2] Schleiden and Vogel,[3] Harz,[4] Nobbe,[5] Sempolowski[6] and Lohde[7] may be mentioned. H. Godfrin,[8] who has examined the seed coats of thirty-four orders, finds that while the structure of the seed coats is useful in some directions, it is of no taxonomic value.[9] Bachmann,[10] in his paper on the development and structure of seed coats of Scrophulariaceæ, says that the microscopic characters of seed coats are of little value from a systematic standpoint.

In the order of presenting the different genera and species of this paper Gray's Manual has been followed. In all twenty-two genera and thirty-four species were studied. The gen-

*A thesis in Department of Botany, Iowa Agricultural College.

[1] GAERTNER: De Fructibus et Seminibus Plantarum, 1791.

[2] BISCHOFF: Handbuch der bot. Terminologie und Systemkunde, 1883.

[3] SCHLEIDEN and VOGEL: Ueber das Albumen insbesondere der Leguminoseen.

[4] HARZ: Landwirthschaftliche Samenkunde, Berlin, 1885.

[5] NOBBE: Handbuch der Samenkunde, Berlin, 1876.

[6] SEMPOLOWSKI: Ueber den Bau der Schalen landwirthschaftlich wichtiger Samen, 1874.

[7] LOHDE: Ueber die Entwickelungsgeschichte und der Bau einiger Samenschalen. Inaugural dissertation, Naumburg, 1874. p. 34.

[8] GODFRIN: Etude histologique sur les téguments seminaux des angiospermes. Nancy, 1880. pp. 112, 5 plates.

[9] L. H. PAMMEL: On seed coats of the genus Euphorbia. Proc. Am. Assoc. Adv. Sc. vol. XXXIX, 1890. p. 328.

[10] BACHMANN: Die Entwickelungsgeschichte und der Bau der Samenschalen der Scrophularineen. Halle, 1880. pp. 179. 4 plates.

eral structure of this order is very characteristic. There are minor differences only in the different species of the same genus and non-essential variations in the different genera.

The seeds of Malvaceæ are anatropous. The seed coat is made up of two integuments. The ovule is made up largely of parenchymatous tissue which in the early stages contains a great deal of starch. Upon the thickening of the endosperm cells this starch disappears.

A cross section of a recently fertilized ovule of *Malope trifida* Cav. discloses that but a slight differentiation in the two integuments has taken place; they are made up of prismatic cells, which in the outer layer are rectangular, while in the inner they are more nearly isodiametric. The difference is not alone in form; the outer integument is distinctly clearer than the inner, which is rich in protoplasm. This indicates that we are to have a more marked change in the inner than in the outer integument. In the course of development the cells of the outer integument change but slightly, simply increasing in size. The small starch grains contained in it disappear with the thickening of the walls of the cell. From the great radial growth of the first layer of cells in the inner integument and the thickening of the outer layer in the outer integument, the second layer of the outer integument is compressed until the upper and lower cell-walls are nearly or quite contiguous.

More decided changes take place in the inner integument. The second cell layer takes on a rounded form while the third layer of cells has been divided parallel to the endosperm. The second layer of cells increases rapidly in size compressing the fourth layer. During this time the first layer has lengthened out radially until the length of a cell is nearly three times its width. This layer is known as the palisade layer, which is so characteristic in this order. The palisade cells contain starch in the early stages. During the thickening of the walls the amount of starch diminishes. When the cell-walls have reached their thickness the starch has disappeared.

In a mature palisade cell, a cell cavity may be seen about one-third the distance from the outer end. These cavities often contain a spherical mass resembling a nucleus, which dissolves readily on the application of Schulze's medium. Between the cell cavity and the outer end of the palisade cell appears the light line which is present in a number of orders.

It appears as a continuous pellucid band (fig. 1 *l.*) across the outer end of the palisade cells. In the Leguminosæ this was noticed, at least as early as 1838, by Schleiden and Vogel.[11] The nature of this light line has been studied by a number of investigators. Quite different views have been taken in regard to it.[12]

Russow,[13] after investigation, comes to the conclusion that the cell-wall is more compact and contains less water at this place. Sempolowski[14] is of the opinion that it may be due to a differentiation in the molecular structure of the cell-walls. Lohde,[15] who studied carefully the development and structure of the seed coats of some Convolvulaceæ and Malvaceæ thinks that it arises from the cuticularization of small particles of the palisade cells. Junowicz,[16] after an exhaustive study, finds that the light line is present only in palisade cells; that the cell-wall at this place refracts light strongly, and that the refraction not due to a chemical change in the cell-wall, i. e., cuticularization. Beck[17] says that it cannot be due to a cuticularization, nor is there a difference in the amount of water contained in that part of the cell-wall, although there are certain chemical and physical differences.

Immediately under the palisade cells are two layers of roundish cells of dark brown color. The number of integuments in the different species studied is the same, and the number of layers of cells in each integument is practically the same.

ALTHÆA ROSEA Cav.; fig. I.—In specimens of A. rosea the outer integument, *a b*, has both layers of cells developed, the outer layer, *a*, being developed rectangularly in a tangential direction. This layer gives rise to the epidermal outgrowths, or seed hair. The next layer, *b*, is nearly isodiametric.

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[11] VOGEL: l. c. Vol. XIX. pars II, taf. XLIII, fig. 55. 58; taf. XLV, fig. 77. 80. Nova Acta der Leop. Car. Academie.

[12] O. MATTIROLLA: La linea lucida nelle cellule Malphigiani degli integumenti seminali. Mem. della R. Acc. delle Sc. di Torino. Ser. II. Vol. XXXVII. See abst. Just's Bot. Jahresb., 1885. p. 825.

[13] RUSSOW: Vergleichende Untersuchungen über die Leitbundel-Kryptogamen, pp. 32. St. Petersburg, 1872.

[14] SEMPOLOWSKI: Beitræge zur Kenntniss des Baues der Samenschalen, p. 11, Leipzig, 1874.

[15] LOHDE: l. c., p. 30, 36.

[16] JUNOWICZ: Die Lichtlinie in den Prismenzellen der Samenschalen, p. 3, p. 18; p. 17. Prag, July 12, 1877.

[17] GUNTHER BECK: Vergleichende Anatomie der Samen von Vicia und Ervum, pp. 32. Sitzb. d. k. Akad. d. Wissensch. Band LXXVII. I. Abth. Mai Heft. 1878.

There is no deposition of intercellular matter in this integument nor between the two integuments. The palisade cell, *c*, is of moderate size. The cell cavity is nearer the upper end than ordinary. Nodosity is not often present. The light line, *l*, is not so sharp or distinct as in many species. The sub-palisade portion, *d*, is made up of a layer of large cells and several small ones. The small cells are narrow. The whole is of a chestnut brown color. The endospermal covering, *e*, is rather delicate. The first layer of cells in the endosperm, *f*, is made up of regular cells.

Measurements: seedcoats, 104μ; outer integuments, 29μ; outer layer of same, 11μ; inner layer of same, 18μ; palisade layer, 52μ; sub-palisade, 23μ.

MALVA SYLVESTRIS L.; fig. II.—The surface of M. sylvestris is rough in appearance. The second layer, *b*, of the outer integument, *a*, has been compressed into a thin layer and seems to have no definite arrangement. The outer layer, *a*, has been elongated radially. In places these elongated cells have divided forming a double layer of cells. There is no brown coloring matter in this integument nor is there any between the integuments. The palisade cells, *c*, are clear; the walls thick. The cell-cavity occupies about one-third the length of the cells, the lower end reaching to the middle. The nodosity is prominent. Below the cavity the cells are clear, almost transparent. The sub-palisade portion, *d*, is usually made up of two layers, at some places only one, of large dark brown cells.

Measurements: seed coats, 122μ; outer integument, 27μ; outer layer of same, 22μ; inner layer of same, 5μ; palisade layer, 70μ; sub-palisade, 25μ.

CALLIRRHOE TRIANGULATA Gray; fig. III.—The inner layer, *b*, of the outer integument is developed into isodiametric cells. The outer layer, *a*, is drawn out tangentially until linear. The cells are colorless and are closely contiguous to the palisade layer. The palisade layer, *c*, is clear throughout, with the borders of the cells sharply defined. Cell-cavity is large and near the upper end of the cells; nodosities prominent. The light line, *l*, is wide and sharply defined. The sub-palisade portion, *d*, is composed of two layers of cells, the cells of the upper layer having very thick brownish walls.

Measurements: thickness of seed coats, 90μ; outer integument, 9μ; inner layer of same, 6μ; outer layer of same, 3μ; palisade layer, 63μ; sub-palisade layer, 18μ; length of sub-palisade layer, 28μ.

CALLIRRHOE INVOLUCRATA Gray; fig. IV.—The outer layer, *a*, of the first integument is developed into large cells. This is just the reverse of C. triangulata. The cells are variable; some are isodiametric; they elongate gradually until some are almost linear tangentially. This layer is colorless. The inner portion of the palisade-cells, *c*, is almost transparent. The cell-cavity is very large and situated nearer the middle of the cell than in most cases. The light line is not sharp and quite near the outer end of the cell. The sub-palisade portion, *d*, is composed of two layers of large cells, the larger being nearer the palisade cells.

Measurements: seed coats, 62μ; outer integument, 8μ; outer layer of same, 6μ; inner layer of same, 2μ; palisade layer, 39μ; sub-palisade, 15μ.

MALVASTRUM ANGUSTUM Gray; fig. V.—The second layer, *b*, of the outer integument is developed into radially elongated cells. These cells are about twice as long as wide. The outer layer contains no coloring matter. The cell-walls between the first and second integument contain a small amount of yellowish coloring matter. On each side of the outer integument is a narrow band, *i*, that refracts light strongly. The palisade cells, *c*, are quite remarkable in having the clearest portion occurring outside of the cavity. This may account for the apparent dimness of the light line, *l*. The position of the light line is normal. The cell cavity is large and the nodosity prominent. The sub-palisade portion, *d*, contains one layer of very large dark brown cells. The large cells take a diagonal position. In some specimens they look like an S. This is not quite so striking in *M. coccineum* Gray.

Measurements: seed coats, 104μ; outer integument, 9μ; second layer of same, 8μ; palisade layer, 65μ; sub-palisade, 30μ.

SIDA NAPÆA Cav.; fig. VI.—The outer integument, *a*, *b*, is composed of two layers of cells about equally developed. The shape in both layers is quite variable, from elongated radially to elongated tangentially. The cell-walls are colored yellowish brown.

The outer portion of the palisade cells, *c*, especially around the cell cavity, is more or less yellowish. The light line, *l*,

is not very prominent and quite near the end of the cells. The lower portion of the cells is colorless, almost transparent. The sub-palisade portion, *d*, is composed of two layers of cells. These cells are large, brown and elongated tangentially.

Measurements: seed coats, 120μ; outer integument, 24μ; palisade layer, 70μ; sub-palisade layer, 26μ.

ABUTILON AVICENNAE Gaertn.; fig. VII.—The outer layer, *a*, of the first integument is transformed into a strongly refractive layer. Thes econd layer is composed of radially elongated cells. The seed hairs arise from a single cell and are large and conspicuous. The hairs are spindle-shaped and thin walled; they occur mostly at the ends of the seed and are more or less pressed to it. There is little or no coloring matter in this integument excepting in the base of the hair cells. The palisade cells, *c*, are narrow for their length. The cell cavity is not prominent and the nodosity is inconspicuous. The light line is narrow and occurs near the outer end of the palisade layer. The sub-palisade portion, *d*, is made up of two layers of light brown cells. They are symmetrical and elongated tangentially.

Measurements: seed coats, 147μ; outer integument, 13μ; palisade layer, 96μ; sub-palisade, 38μ.

MODIOLA MULTIFIDA Moench.; fig. VIII.—The first layer, *a*, of the first integument is developed into tangentially elongated cells. The second layer, *b*, has been compressed into an irregular shape. This layer contains much yellowish coloring matter. The palisade layer, *c*, is clear, almost transparent, the cell cavity long and the nodosity not conspicuous. Both the cell cavity and the nodosity lack the yellow color usually present. The light line, *l*, is indistinct. The subpalisade portion, *d*, seems to be made up of two layers of cells. The cells of the different layers alternate. The outer layer is composed of very large spherical cells. The second layer is also made up of spherical cells but not so large as the outer; both are of dark chestnut brown color. Below this is a thick portion of irregularly shaped cells of brown color.

Measurements: seed coats, 84μ; outer integument, 14μ; palisade layer, 32μ; width of same, 4μ; sub-palisade, 38μ; diameter of upper layer, 26μ; diameter of lower layer, 14μ.

HIBISCUS MILITARIS Cav.; figs. IX, X, XI.—The first layer, *a*, of the outer integument is most prominently developed. This layer gives rise to the seed hairs. These hairs, *h*, are spindle-shaped, with the walls thin and fragile. The walls of the basal cell are stronger than the neighboring cells. The seed hairs are made up of single cells each containing a small amount of granular matter at the base. The color of the integument is chestnut brown. Cells in the second layer, *b*, are elongated tangentially. The palisade layer, *c*, is composed of large cells, wide in comparison with their length. The cell-cavity is comparatively small, the nodosity prominent. The light line, *l*, is strong and large. Under ordinary magnification ($\frac{1}{6}$ objective) it appears as an unbroken band across the outer end of the cells. Using a strong magnification ($\frac{1}{10}$ or $\frac{1}{16}$ oil immersion) each cell-wall interrupts the line. The portion of the light line in each cell is divided or nearly divided into two or three bodies. Under an analyzer the light line takes on blue a little earlier than the adjoining field. When the field is most intense blue the light line is dark on the inner border and dark blue on the outer. Just before the section comes into focus the light line appears dark taking on the characteristic colors when in focus, while the color of the adjoining field does not depend upon the focus. A thick section shows the following colors under the analyzer, blue, green, yellow, pink. The colors appear only above the cell-cavity. The portion below the cell-cavity gives only blue and yellow distinctly. The cell-cavity agrees with the upper portion of the cells. The nodosity does not change polarized light. The other cells of the seed-coat give no decided reaction under the analyzer. After isolation a cell parts easily immediately below the cavity and sections often behave in a similar manner. The cells, fig. X, are usually pentagonal and somewhat elongated in the direction of least circumference. (Fig. XI.)

The sub-palisade portion, *d*, is composed of three prominent layers and a number of less regular closely massed cells. This layer has a great amount of dark coloring matter, which is a dark chestnut brown.

Measurements: seed coats, 187μ; outer integument, 26μ; outer layer of same, 17μ; inner layer of same, 8μ; palisade layer, 103μ; sub-palisade layer, 58μ.

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